Fire and Vegetation History of Santa Rosa Island, Channel Islands National Park, California

Final Report for A Cooperative Agreement (1443CA8000-8-0002)

Between Channel Islands National Park & Northern Arizona University

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INTRODUCTION

This report details the research conducted primarily on Santa Rosa Island, Channel Islands National Park, under a cooperative agreement between the National Park Service and Northern Arizona University. Research undertaken within this agreement seeks to determine the fire and vegetation history of Santa Rosa and San Miguel Islands, using paleoecological methods. Paleoecologists, those that study ecosystems of the past, analyze fossil plant remains recovered from lake, meadow and wetland sediments to understand the biogeography and disturbance history of an area. Increasingly this research on paleo-historical vegetation associations has attracted the attention of land managers and others for reasons that include the potential for rapid and substantial changes in vegetation composition, fire occurrence and insect infestation due to predicted future climate changes.

Plant communities are continuously stressed by environmental variables, such as natural disturbance, climatic perturbations and human activities, and exhibit changes in structure and species composition on several time scales. Some agents such as human activities and fire operate over years to decades. Records of these are often gleaned from historical accounts, matching photographs and, if trees are present, from the tree-ring record. On somewhat longer timescales, on the order of 100's to 1000's of years, changes in vegetation and disturbance regimes are most often linked to climatic perturbations. Since proxy records of vegetation change from historical accounts are in short supply for the Channel Islands, and species of trees with long fire-scar records are absent there, our best hope of obtaining information on changes in vegetation and variations in fire history through time come from sediments that have accumulated on the Islands.

Commencing with a visit to Santa Rosa and San Miguel Islands in June 1999 we collected sedimentary profiles from basins on Santa Rosa and San Miguel for analysis of fossil pollen, plant macrofossils and sedimentary charcoal particles. Our goal has been to examine the changes in these proxies through time in order to determine former ecosystem characteristics during the Holocene – approximately the last 11,000 calendar years. We were successful in identifying a coastal and an inland site on Santa Rosa Island, and our efforts have been concentrated on reconstructing the records there. A single day was spent on San Miguel Island and less effort was spent on this record.

Results from our investigations have yielded significant findings on the history of vegetation change and fire from a site near sea level on the eastern coast of Santa Rosa Island - Abalone Rocks Marsh – as well as a site in the interior, that we have informally called Soledad Pond. In addition, this report details efforts to collect and identify the modern pollen of the Island, as well as to identify older materials collected from deep canyon profiles on the north shore. A small section is devoted to the small amount of work that we have accomplished from San Miguel Island.

FIELDWORK

Fieldwork on Santa Rosa Island (SRI) was conducted from 2 June to 11 June 1999. Initial reconnaissance of SRI was land-based vehicles, assisted by Sarah Chaney of the NPS. Our primary objective was to identify small ponds, seasonal wetlands and estuaries that might contain a sedimentary record. (Sediments can be analyzed for their pollen content – to deduce vegetation change – and for their charcoal content – to investigate the fire history of the island). A secondary goal was to obtain necessary reference materials, primarily flowers from plants growing on the island, to build a pollen reference collection with which we would compare the fossil pollen isolated from the sediment cores. Our tertiary activities included preliminary reconnaissance of deeply incised canyons on the north and northwest of Santa Rosa Island to determine the potential for finding a Pleistocene record of vegetation there.

Identification and Coring of Wetlands. We investigated several small basins on the Islands. On SRI these included

(1) a vernal pool at Water Canyon;
(2) small swales on the Carrington Point dune field;
(3) small swales near Skunk Point and East Point;
(4) wet areas along Old Ranch Canyon road;
(5) Abalone Rocks Marsh;
(6) a small vernal pool informally called Soledad Pond;
(7) depressions near Beef Pasture and the turnoff to Orr's camp;
(8) small pools along the Burma Road;
(9) several of the Pocket Field pools; and
(10)a small pond off of the Pablo Peak road.

On SMI we made a cursory examination of the Dry Lake area near the present airstrip.

Once we determined which sites that were likely to provide a record of vegetation and fire histories for SRI we collected sediment profiles from two locations. The first, informally termed Soledad Pond, was a seasonal wetland located approximately in the middle of the island (Santa Rosa Island North USGS 7.5' Quad; 33° 57' 55" N, 120° 05' 50" W). The site is approximately 1.8 km from Soledad Mountain and 2.4 km from Black Mountain. Located at ca. 275 m (875') above sea level, the pond is surrounded primarily by grasses and herbs. Plant species that we (Sarah Chaney, Mitchell Power and myself) identified within the drainage area of the pond included those listed in Table 1. The sediment column was collected by first digging a pit in the middle of the pond, which was completely dry at that time. We also collected "moss polsters", small moss cushions that serve a mini-depositional sites for modern pollen assemblages.

The second site was located on the extreme eastern end of the island, and is informally known as Abalone Rocks Marsh. This marsh, a small estuary, and was originally studied by Cole and Liu (1995). We required a new sediment record to test several hypotheses relating to fire and vegetation history, sea-level change and erosion of the uplands. Abalone Rocks Marsh is located on the Santa Rosa Island East USGS 7.5'Quad, at 33° 57' 20" N and 119° 5' 45" W. The site is essentially at sea level. We collected several moss polsters from this location as well.

From each of these sites we extracted a sediment profile of variable length (see below) by either obtaining a sediment core using a Livingstone sediment corer (Abalone Rocks Marsh) or by digging a pit in the deepest part of the basin (Soledad Pond). The Livingstone corer takes a sediment column 5 cm in diameter and can obtain core segments up to 1 m in length by repeatedly entering the same hole and taking successively deeper segments. Using this corer we obtained 3 cores, the longest being 676 cm. For Soledad Pond, our record was extended to a

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TABLE 1. Plants identified around Soledad Pond (7 June 1999)*

Agrostis sp.	*Lactuca saligna*
Anagallis sp.	*Lolium perenne*
Avena barbata	*Madia* sp.
Baccharis pilularis	*Malva parviflora*
Bromus diandrus	*Marubium vulgare*
Bromus hordeaceus	*Medicago polymorpha*
Capsella bursa-pastoris	*Petunia parviflora*

Centaurea melitensis
Chenopodium epizote
Conyza canadensis
Cotula coronopifolia
Erodium cicutarium
Gnaphalium luteo-album
Hirschfeldia incanum
Hordeum geniculatus
Hordium murinum
Juncus sp.
Polygonum aviculare
Polypogon monspeliensis
Sanicula arguta
Silene gallica
Sisyrhinchium bellum
Silybum marianum
Sonchus oleraceus
Verbena lasiostachis
Vulpia sp.
Xanthium spinosum

* Identified by Sarah Chaney

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greater depth by using a soil auger to collect sediment from levels below the bottom of the pit. The upper sediments from Soledad Pond were sampled from the exposed pit face. We sampled the upper 210 cm in a continuous set of 10-20 cm blocks, and from 210 to 425 cm in 5-cm blocks with the bucket auger. Each of the sediment columns was either wrapped in plastic wrap, then aluminum foil (Abalone Rocks Marsh and upper portion of Soledad Pond), or placed in plastic whirlbags (bottom portion of Soledad Pond). Sediments were transported to the Laboratory of Paleoecology (LOP), Bilby Research Center, Northern Arizona University, where they are presently stored.

A third site was examined and sediments were collected from San Miguel Island. We obtained a sediment column from a site immediately adjacent to the airstrip in the Dry Lake bed. Location of this site is on the San Miguel Island West USGS 7.5' Quad at 34° 02' 40" N and 120° 24' 35" W. A total of 127 cm of sediment was obtained with the auger.

Collection of Modern Pollen. We also collected flowers from plants near the sites and around the Islands for modern pollen reference materials. These modern specimens have allowed us to compare fossil pollen found in the sediment profiles with pollen from species extant on the island today. Using these samples, we can determine the characteristics of the vegetation of former times.

Examination of Potential Pleistocene Alluvial Sections. We collected samples from three canyons on the north side of Santa Rosa Island. Two pollen samples were collected from Verde Canyon (labeled Verde #1 and #2). Four were collected from Tecolote Canyon (labeled Tecolote #1 organic stringer 55', #2, #3 blackmat, and #4. Three pollen samples were collected from Arlington Canyon. In addition, wood samples

were collected from near the base of alluvium in Arlington Canyon (Santa Rosa Island North USGS 7.5' Quad; 33° 58' 30" N and 119° 09' 30" W), yielding the oldest radiocarbon date collected from the Islands so far (see Table 2 below).

LABORATORY METHODS

Laboratory methods consisted of processing sediments and modern pollen samples to extract charcoal and pollen assemblages. In addition, selected sediment depths have been subjected to dating techniques to produce the chronology explained below.

Charcoal Analysis: Charcoal analysis followed a modified methodology developed by Millspaugh and Whitlock (1995). Sediment subsamples (5 cc for Soledad Pond; 2 cc for Abalone Rocks Marsh) were extracted from each level analyzed in the profiles and placed in water for several days to dissolve the sediments. Each subsample was then wet-sieved using 0.125 and 0.250 μ sieves to separate different size fractions of charcoal. Under a dissecting microscope (magnification of 10 to 70 X), each sieved sample was examined for its charcoal content, and the individual charcoal particles were tallied. Charcoal was identified by reference to particle color and texture - most charcoal particles are shiny black, and often retain cellular structure (Anderson *et al.* 1986). Charcoal concentration was calculated by dividing the number of charcoal particles counted per size category by the volume of sediment. The concentration of particles in each size class was then summed to produce a total charcoal concentration for each level analyzed, and charcoal influx data were calculated.

The charcoal influx data was analyzed using charcoal analysis software from the University of Oregon that decomposes the charcoal accumulation rate (CHAR) into a background component (considering varying charcoal production and sedimentation) and a peak component (representing the charcoal input from a fire event in the watershed) (Brunelle and Anderson 2003). When the CHAR of a sample exceeds background by a predetermined amount or threshold ratio, that particular interval is designated as a "peak". The CHAR time series is created by interpolating charcoal concentration values (particles / cm^3) and deposition times (cm/yr) into pseudo-annual values (Long *et al.* 1998; Mohr *et al.* 2000). The background component was calculated by applying a 400-year locally weighted moving average to the CHAR time series. A

peak threashold value of 1.05 was then used to compare the background component to each CHAR value for each interval. Individual time intervals with CHAR values exceeding the background value assigned to that interval were designated as peaks. The binary series of peaks was then smoothed to produce a mean frequency of fire events / 1000 years (see Discussion section).

Pollen Analysis: Pollen analysis was performed by two similar procedures. Modern pollen was the easiest to extract, and followed a modified procedure outlined by Fægri and Iversen (1989). This included taking individual flowers (or anthers) and suspending in KOH (to loosen the pollen), dilute HCl (to remove carbonates), and acetolysis solution (a sulfuric acid solution, to digest non-pollen organic matter). The resulting pollen was stained with safranin and suspended in silicone oil on a glass slide.

Fossil pollen analysis followed a more detailed procedure. Usually 10 cc (Soledad Pond) or 2 cc (Abalone Rocks Marsh) of sediment were processed. Pretreatment of sediment with sodium hexametaphosphate deflocculated the clays; this was followed by addition of *Lycopodium* tracer tablets for calculation of pollen concentration. Subsequent steps included suspension in sodium pyrophosphate with sieving (to remove clays), HCl treatment, suspension in HF (to dissolve silicates), acetolysis, and density separation in zinc bromide (specific gravity 1.9). These samples were stained and suspended in silicone oil like the modern pollen samples. The resulting pollen assemblages were examined at 400 - 1000 X using a light microscope, with comparison to the modern pollen reference collection at the Laboratory of Paleoecology at NAU.

Sediment Dating: To provide a chronology for the charcoal and pollen sequences, we used three methodologies. For the youngest parts of the Soledad Pond and Abalone Rocks Marsh profiles we use pollen and historical data to assign a calendar age to the time of regional and local settlement by Euro-Americans. Settlement and initiation of cattle ranching within coastal California occurred by the late 1700's AD (Mensing and Byrne 1998). This event is registered in other sediments of mainland coastal California, and in the offshore sediments of the Santa Barbara basin, by the first occurrence of pollen of weedy plants, including *Erodium cicutarium* (red filaree), which is most often associated with cattle operations (see below for details). For older sediments in Soledad Pond we used radiocarbon dating to establish the ages of the sediment column (Table 2). Our age estimates for Abalone Rocks Marsh are made by

comparing the pollen stratigraphy of a core completed by Cole and Liu (1995). Radiocarbon dates are not identical to calendar ages, and so we used a conversion program (Stuiver and Reimer 1993) to convert the radiocarbon dates to calendar years AD (before present).

TABLE 2. Radiocarbon Dates for Soledad Pond and Arlington Canyon Wood Samples

Profile	Lab #	Depth (cm)	Age C-14 yr BP*	Age Calendar yr BP*
Soledad Pond	Beta-172056	210-215	4,100 ± 50	4,820 to 4,440 BP
Soledad Pond	Beta-172057	335-360	8,990 ± 60	10,230 to 9,930 BP
Soledad Pond	Beta-150252	415-420	10,160 ± 110	12,580 to 12,520 BP
Arl.Cyn Wood	Beta-150251	750 below datum	17,050 ± 240	21,180 to 19,440 BP

*BP = Before Present

Pollen and Charcoal Diagrams: Pollen data are traditionally presented in "pollen diagrams", which represent the changes in pollen percentages through time (Figure 1). The vertical axis represents depth in the profile, usually in cm below the surface (far left in the diagram). The vertical axis also represents time, with the modern period at the top of the diagram, and increasing age with depth (also far left). The percentage of pollen for each pollen taxon for each level analyzed is shown. Each taxon's percentage is a fraction of the total number of grains identified for each level - the total number of pollen grains equaling 100%. Dots on the diagram signify that the pollen type was present in the sample at that level, but in very small amounts. For the charcoal record, the horizontal axis represents the amount of charcoal present in each sample (each bar in the "Total Charcoal" column represents the amount of charcoal at a particular depth in the profile).

Using these data one can identify (1) the changes in the importance of species or vegetation assemblages (as seen by changes in pollen percentages) through time, and (2)

the changes in fire occurrence (registered by changes in charcoal amounts). Later we use the charcoal data to calculate a general measure of fire frequency changes through time.

RESULTS

Modern Pollen Collections: We collected pollen from 53 of the most common plants in flower at the time of fieldwork. Our modern pollen reference collections came from 14 sites on SRI and one site on SMI. These collections are detailed in Appendix 1 (Modern Pollen Collections on Santa Rosa and San Miguel Island). Added to the collections that we made previously on Santa Cruz Island, we now have modern pollen from 97 plant taxa that occur on the Channel Islands.

Separation of Pollen of the Asteraceae. Because so many species of the family Asteraceae occur on SRI (up to 95 [Junak *et al.* 1995]) we attempted to subdivide as many members of this family into different pollen subgroups as we could. On the basis of examples of pollen in our possession we identified 11 subgroups. These included the ragweed group (*Ambrosia*-type), sagebrush/wormwood (*Artemisia*-type), thistle (*Cirsium*-type), chicory (Lactuceae-type), coyote brush (*Baccharis*-type), sunflower (*Helianthus*-type), pincushion flower (*Chaenactis*-type), goldenrod (*Solidago*-type), yarrow (*Achillea*-type), island chicory (*Malacothrix*-type) and eriophyllum (*Eriophyllum*-type) (Appendix 2). All of the pollen subgroups included more than one genera except the last two listed. The most common pollen subgroup identified was the *Baccharis*-type.

Soledad Pond: Located nearly in the center of the island, Soledad Pond provided a record at least 425 cm in length, dating to at least 12,000 calendar years old (all subsequent ages are reported in calendar years). The age of the bottom sample makes the record from Soledad Pond the oldest continuous record from SRI, and one of the oldest records from the Channel Islands. Thirty-six pollen samples were analyzed. Two pollen diagrams were constructed for this record. Figure 1 shows major pollen types within the record, while Figure 2 shows just the different groups within the sunflower family (Asteraceae). Based upon major changes in pollen taxa four distinct periods can be differentiated.

Late-glacial transitions (core bottom to ca. 10,000 years ago). Pollen is dominated by the sunflower family (Asteraceae), with the major subgroups of chicory-type (Lactuceae) and coyote brush (*Baccharis*). Small amounts of grass (Poaceae)

pollen are found, along with pollen of coastal sage scrub (i.e., buckwheat [*Eriogonum*], rose family [Rosaceae]) and other plants (phlox family [Polemoniaceae] and sedge [Cyperaceae]).

Early to Middle Holocene (ca. 10,000 to 4,600 years ago). Pollen richness in this zone is less than any other zone. It is dominated by sunflower family pollen, but other than small amounts of coyote brush type pollen, it is not diagnostic of any other subgroup. Most other pollen types, including grass pollen, disappear or become rare during the early part of this time period, but reappear near the end.

Late Holocene (ca. 4,600 years ago to ca. 1800 A.D.). Most of the pollen types found in the lowest zone become important again, including coyoto brush and chichory type in the sunflower family, along with members of the coastal sage scrub (buckwheat, rose family, legume family [Fabaceae]), phlox family, and carnation family (Caryophyllaceae). Grass pollen reappears, and pollen of wetland plants (i.e., sedge and carrot family [Apiaceae]) are also prominent.

Historic Period (since ca. 1800 A.D.). Pollen of the sunflower family continues to be the dominant pollen type. However, grass pollen is most abundant during this time period, and the widespread indicator of pastoral and grazing, filaree (*Erodium*) is an important pollen type in this zone. Pine (*Pinus*), oak (*Quercus*) and ragweed (*Ambrosia*) pollen also are most abundant here (not shown).

The charcoal record for Soledad Pond sediments shows abundant charcoal occurring throughout the section (Figure 3), indicating fire has been an important process here for the last ca. 12,000 years. With exception of two large charcoal peaks at ca. 150 and 160 cm depth, charcoal amounts are relatively consistent throughout the profile. However, charcoal deposition becomes much greater above ca. 80 cm depth. This occurs during the historic period, since 1800 A.D.

Abalone Rocks Marsh: We obtained three sediment cores from Abalone Rocks Marsh, a site originally studied by Cole and Liu (1995). Our goal in re-coring this location was to be able to perform additional analyses at this site. The column obtained by Cole and Liu at the marsh was ca. 5.4 m, and produced a record of ca. 5,200 ^{14}C years. Since our core 99-3 from the marsh was somewhat longer at ca. 6.76 m, comparison with the original core of Cole and Liu suggests that this new record is ca. 6,150 ^{14}C years, or over 7,000 calendar years, old. Comparison of our pollen stratigraphy with that of Cole and Liu suggests that major changes occur in the core at

approximately 1800 A.D. (ca. 100 cm depth), and ca. 3,465 calendar years (3,250 ^{14}C years at about 400 cm depth). At present we do not have radiocarbon dates to confirm this.

We performed additional analyses on the Abalone Rocks Marsh record not performed at Soledad Pond, including magnetic susceptibility of the sediment core (Figure 4) and diatom concentrations (Table 3). Since magnetic susceptibility measures the degree to which sediments can be magnetized this is an important measure of erosion and deposition within the basin. Magnetic susceptibility is highest in the top ca. 80 cm of the record, suggesting erosion rates were considerably higher during the historic period when these sediments were deposited. Additional periods of higher magnetic susceptibility occur centered around 340, 390, 420 and 455 cm depth.

For the pollen record we were again able to differentiate the Asteraceae into 11 subgroups (Figure 5). In addition, our analysis differentiated at least nine fern and fern allies (Figure 6), many of which have been identified to generic groupings. The pollen stratigraphy shows that three dominant periods of vegetation change have occurred in this record.

Middle Holocene (ca. 7,000 to 3,465 years ago). Dominant pollen from this period (zone 3) includes members of the goosefoot family (Chenopodiaceae), with some grasses (Poaceae) (Figure 5). The goosefoot family includes many species that are salt-tolerant. The dominant subgroup of Asteraceae is the *Baccharis*-type, although this group is not as important as somewhat later in the record. Small amounts of pine (*Pinus*), oak (*Quercus*) and isolated chaparral and sage scrub (e.g., sagebrush/wormwood [*Artemisia*] and buckwheat [*Eriogonum*]) plants are found throughout the record. According to Cole and Liu (1995) this is a period in which marine conditions may have dominated over freshwater conditions in the estuary.

Late Holocene (ca. 3,465 years ago to ca. 1800 A.D.). During this period (zone 2) the goosefoot family (Chenopodiaceae) pollen type is reduced, and the record is dominated by upland pollen types, especially the *Baccharis*-type (Figure 5). Other important upland plants include buckwheat (*Eriogonum*), gilia (*Ipomopsis/Gilia*) and several of the subgroups of the Asteraceae. Many species of ferns and fern allies become important during this time period, some of which are at present unidentified. For instance, spike moss (*Selaginella* cf. *bigelovii*) is nearly confined to this time and later (Figure 6). This period may reflect an increase in freshwater input into the marsh,

and greater development of vegetation on the surrounding uplands. The former interpretation is enhanced by the occurrence of quillwort (*Isoetes*) spores, a macroalgae confined to freshwater.

Historic Period (since ca. 1800 A.D.). The most recent two hundred years (pollen zone 1) is contemporaneous with the historic occupation of the Island, and is differentiated by the occurrence of pollen of several introduced species, including filaree (*Erodium*) and Monterey cypress (*Cupressus macrocarpa*), and later by *Eucalyptus*. Goosefoot (Cheno-Am) pollen also increases in the later portion of the zone, and may represent an additional introduced species, such as one of the alien *Chenopodium* or *Atriplex* species now common on the island (Junak *et al.* 1995). The number of fern and fern allies spores dramatically increases during this time, with increases in *Botrychium*, *Pellaea*, *Adiantum* and *Polypodium californicum*, as well as several unidentified spores (Figure 6).

The diatoms from the Abalone Rocks Marsh core were analyzed by Scott Starratt of the USGS. Though relatively few diatom valves were recovered from the sediments, especially below ca. 300 cm depth, differentiating species into ecological preferences (Appendix Table 3) shows that species that are freshwater, or prefer fresh- &/or brackish water are most abundant in zones 1 and 2. Counts of diatoms that prefer brackish, brackish and marine, and marine conditions are considerably fewer of the valves identified throughout. But of the latter group, a somewhat larger number are found in zone 3 than in the other two zones. This may suggest that inundation of the marsh by marine water may have been more frequent in the early part of the record than in the latter portion.

The charcoal record from Abalone Rocks Marsh (Figure 7) is very different from that of Soledad Pond. For Abalone Rocks Marsh large concentrations of charcoal alternate with sediments containing virtually no charcoal at all. The individual charcoal "spikes" may represent individual fires within the drainage of the marsh. Of special note is the very low concentrations of charcoal during the historic period. This also contrasts with the record from Soledad Pond, where charcoal concentrations are very high (see Discussion section below).

<u>Dry Lake, San Miguel Island</u>: A minimal number of pollen samples were identified from a sediment core taken from the Dry Lake area of SMI. With only three samples analyzed little can be concluded about this short record (not shown). A number

of subgroups of the Asteraceae family are present throughout the ca. 115-cm profile. Members of the goosefoot (Cheno-Am) and grass (Poaceae) families increase toward the surface of the profile, as does filaree (*Erodium*).

Arlington Canyon Wood: In an effort to evaluate the potential for obtaining a Pleistocene pollen record, we identified sediments near the stream level of several canyons, including Arlington Canyon, that are of late Pleistocene age. A small branch of wood protruding from the exposure of the canyon wall – ca. ca. 7.5 m below the top of the profile, and ca. 1.0 m above the modern stream level – had a radiocarbon date of 17,050 ± 240 yr BP. Although pollen samples were also taken from these strata, they contained no preserved pollen in them.

Other Studies: In association with the efforts mentioned immediately above, we sampled two Pleistocene strata for pollen in Verde Canyon, and four similar strata in Tecolote Canyon. Samples were processed and did not contain pollen either.

DISCUSSION

The sites in this report represent the most comprehensive analysis of long-term vegetation and fire history on the Channel Islands. In this section I place the paleoenvironmental data in context with that from other sites in southern California on the mainland.

The Late Pleistocene. The vegetation of the late Pleistocene is not well known in southwestern California, and is limited to only a handful of sites. Anderson *et al.* (2002) documented a site in Riverside County dating to ca. 41,000 yr BP (middle Wisconsin). Other sites with paleovegetation information in the time range of the middle to late Wisconsin include the Mystic Lake Slough deposits (Anderson *et al.* 2003); the Rancho La Brea flora (Frost 1927; Warter 1976; Marcus and Berger 1984, Shaw and Quinn 1986; Stock and Harris 1992); and the paleoflora of the Carpenteria (>38K ^{14}C yr B.P.; Chaney and Mason 1934; Fergusson and Libby 1964) and McKittrick (ca. 38K to 10K ^{14}C yr B.P.; Mason 1944; Berger and Libby 1966) sites. In the southern San Joaquin Valley is the Tulare Lakebeds site (Atwater *et al.* 1986; Davis 1999) spanning most of the Wisconsin. From marine cores in the Santa Barbara Basin, Heusser (1995, 1998) documented continuous change in upland vegetation for portions of southwest California over the last interglacial-glacial cycle. Considering most of the inland sites, pollen from this time period is dominated by conifers such as pine (*Pinus*), fir (*Abies*) and juniper/cypress (*Juniperus/Cupressus*), unlike that of today which is dominated by non-trees. In fact, pollen of

this time period is similar in many respects to pollen deposited ca. 800 to 1000 m higher today in the mixed conifer forests of the San Jacinto and San Bernardino Mountains (Anderson and Koehler, in press). Anderson *et al.* (2002) suggested that such a lowering amounted to ca. 4 to 5 ° C cooler average annual temperatures.

Similarly, records from two coastal sites record the occurrence of a coniferous forest during the late Pleistocene. The Cañada de los Sauces florule analyzed from an arroyo exposure on Santa Cruz Island was first described by Chaney and Mason (1930) and subsequently dated to 14,200 ± 250 yr BP by Fergusson and Libby (1963). The florule consists predominantly of coastal douglas-fir [*Pseudotsuga* (*taxifolia*) *menziesii*], Santa Cruz Island pine (*Pinus muricata* forma *remorata*), and Gowen cypress (*Cupressus goveniana*) forest with a diverse understory. Today the site is dominated by introduced grasses, but Chaney and Mason (1930) compared the Pleistocene flora to modern coastal conifer forest near Fort Bragg, some 700 km north along the California coast. On San Miguel Island, also presently covered by introduced grasses, late Pleistocene (< 13,000 cal yr BP) sediments from a small rockshelter at 10 m elevation on the northeast shore are dominated by pine pollen percentages of up 77 % (West 1994). These data suggest that pine (perhaps *Pinus radiata*; Johnson 1977) covered parts of the island during the Pleistocene; with the subsequent extirpation of pine on the island, non-arboreal vegetation predominated.

Late Pleistocene pollen spectra from the Santa Barbara Basin to the west are dominated by pine and other conifers (Heusser 1978, 1995, 1998). Oaks, as well as alder (*Alnus*) are also important. In general, sediments deposited in deep, nearshore basins such as the Santa Barbara Basin receive their major pollen input from rivers and streams draining the nearby uplands. These marine data confirm the importance of trees, particularly pines, in the coastal zone during the late Pleistocene, in regions dominated by non-arboreal vegetation today.

The minimal occurrence of conifer pollen in the Soledad Pond sample deposited during the latest Pleistocene suggests either that tree species were confined mainly to the lower elevations of the Island during this time, or that the transition to largely non-arboreal vegetation was relatively rapid. This was a period of major geographic change in the northern Channel Islands associated with the worldwide sea level rise. The ancestral island of Santa Rosae become separated into the four islands present today (Kennett *et al.* 1994), while warmer, oxygen-poor waters developed in the adjacent Santa Barbara Basin (Kennett and Ingram 1995).

The Early Holocene. Data from the early Holocene is very rare in this part of North America. At Mystic Lake Slough, pollen is virtually absent from early Holocene sediments, dating here to approximately 9,900 to 6,600 yr BP (Anderson 2003). Sediments in this core interval are calcareous silty clays with interspersed sand layers above, with a distinct zone of calcareous rhizoconcretions. The combination of a lack of preserved pollen, along with abundant calcareous rhizoconcretions suggests arid conditions with generally lowered groundwater tables. The date of ca. 8,900 yr BP from the adjacent augerhole at the base of the zone of highest concretion concentration suggests the most arid period was ca. 8,000 to 9,000 years ago. Cores from the Santa Barbara Basin (Heusser 1978, 1995, 1998) show pollen spectra with a decline in pine (*Pinus*), and an increase in oak (*Quercus*) and sunflower family. These changes are also suggestive of progressive drying during the early Holocene.

Pollen data from Soledad Pond also suggest increased dryness at this time on SRI. Pollen richness declines at this time. This, along with a lack of aquatic pollen indicators may indicate that the pond was primarily dry and shrubs such as coyote brush (*Baccharis*) covered the nearby hillslopes.

The Middle and Late Holocene. Many more sites from southwestern California document only the middle and late Holocene time periods. These include two inland sites (Cleveland Pond and Zaca Lake [Mensing 1993]), two mainland coastal sites (San Joaquin Marsh [Davis 1992]) and Las Flores Creek [Anderson and Byrd 1998]), and the original Abalone Rocks Marsh study (Cole and Liu 1995). Two additional sites, Los Penasquitos Lagoon and Mission Bay (Mudie and Byrne 1980) yielded primarily historic sediments only.

The Santa Barbara Basin record suggests that by the beginning of the middle Holocene coastal conifer forest had declined, replaced by a vegetation assemblage where oaks and grasses dominated (Huesser 1978). Expansion also of coastal sage scrub and chaparral communities are also indicated. However, maximum Asteraceae pollen deposition occurs into the late Holocene while the marine core record suggests that maximum extent of the chaparral and coastal sage scrub (pollen types of sagebrush, Rosaceae, Rhamnaceae, Anacardiaceae) occurred during the late Holocene (Heusser 1978).

At Mystic Lake Slough (Anderson 2003) sediments deposited during the middle Holocene contain abundant well-preserved pollen. Plants from the Asteraceae, possibly encelia (*Encelia farinosa*) and mule fat (*Baccharis viminea*), dominate the pollen assemblage, along with *Ambrosia*, grass and, especially during the late Holocene, Chenopodiaceae. Thus, pollen deposited here is suggestive of herbaceous and shrubby vegetation, not unlike the modern mix of

grassland with sage scrub and chaparral vegetation types on the surrounding slopes. The sediment, composed of overbank deposits, suggests that water tables once again rose high enough to wet the sediments and, at times, water actually flowed across the coring site. The pollen assemblages of this time period are consistent with modern pollen deposited at low elevations within the area (Anderson and Koehler, in press).

The record from a site in the San Bernardino Mountains, Dollar Lake, at 2810 m elevation shows contemporaneous vegetation change but at higher elevations (Anderson *et al.* 2001). Dollar Lake was also dry during the early Holocene, but by ca. 5000 years ago held permanent water. An open forest of lodgepole (*Pinus contorta*) and ponderosa (*P. ponderosa*) pines with montane chaparral shrubs in the understory early in the record was replaced by more closed forest with fir (*Abies*) after ca. 3300 years ago. Other high elevation sites nearer the coast include Cleveland Pond (1070 m elevation; Los Angeles County) and Zaca Lake (730 m; San Rafael Mountains, Santa Barbara County) (Mensing 1993). Both records, though relatively invariant through time, show that modern vegetation developed by the late Holocene there as well.

The Las Flores Creek record comes from Camp Pendleton, San Diego County, and covers the last ca. 4800 calendar years (Anderson and Byrd 1998). The site, presently approximately 6 m above sea level, has not been influenced by late Holocene marine inundation. Pollen from riparian plants, including cattail (*Typha*) and sedges (Cyperaceae), is common throughout the section, but by ca. 3000 years ago a vegetation mosaic including elements of the coastal sage scrub, chaparral and grassland communities were established near the site, persisting until the introduction of exotic weed and tree species within the last century. The timing of late Holocene expansion of coastal sage scrub is nearly identical to the record from the Santa Barbara Basin.

The Cole and Liu (1995) Abalone Rocks Marsh record is very similar in many respects to the present study of Abalone Rocks Marsh. Cole and Liu determined that marine sediment dominated the early portion of the record, with high abundance of salt-tolerant plants. Pollen dominance changed after ca. 3,500 years ago to sunflower family pollen with sedges, signifying increased freshwater input. This lasted until ca. 1800 AD, when significant changes associated with European settlement occurred. At Soledad Pond, the major change occurs at ca. 4,000 years ago, with increases in plants characteristic of the coastal sage scrub and grassland communities. An increase in wetland plants (i.e., sedge and carrot family [Apiaceae]) indicates higher groundwater tables, and a more frequent wetting of the pond sediments.

Clearly the period beginning ca. 6000 to 5000 years ago witnessed an increase in effective precipitation throughout southwestern California. That trend was intensified prior to ca. 3000 years ago at higher as well as lower elevation sites.

Historic Period. The pollen record from both Abalone Rocks Marsh and Soledad Pond demonstrate the impact of Euro-American settlement and land use changes on SRI after ca. 1800 AD (Figures 1 & 5). At both locations the sediment accumulation rate increases substantially during the most recent ca. 200 years. For Abalone Rocks Marsh, sediment accumulation in the estuary increases from ca. 0.09 cm/year prior to settlement to ca. 1.0 cm/year – a 10-fold increase. At Soledad Pond, the presettlement accumulation rate is 0.025 cm/yr, but increases also to ca. 1.0 cm/yr. This amounts to a nearly 40-fold increase in sediment accumulation. The historic rates of erosion into the basins are, as far as can be determined, unprecedented during the Holocene for this island.

Furthermore, pollen evidence documents the introduction of non-native plant species to the island during this period. The establishment of filaree (*Erodium*), a plant characteristic of grazing and pastoral pursuits, is found at both locations, and must have spread rapidly across the island. Establishment of populations of Monterey cypress (*Cupressus macrocarpa*) and gum (*Eucalyptus*) is recorded in the Abalone Rocks Marsh record. These species were planted near the historic ranch site at Beechers Bay to the northwest of the marsh. An additional introduced species shows up at Abalone Rocks Marsh during the later portion of the period. This may be an alien *Chenopodium* or *Atriplex* species now common on the island (Junak *et al.* 1995).

Fire History. Determining the relative impact of fire on the island ecosystem through time was a major goal of this project. We used a methodology (Millspaugh and Whitlock 1995; Long et al. 1998; Brunelle and Anderson 2003; Whitlock and Anderson ,in press) that allows for the high-resolution analysis of fire history by calculating the background values of charcoal and differentiating them from the "peak" value (see Methods section). In this manner we determined a measure of "fire event frequency" for the two sites. Values of fire event frequency should be interpreted with caution, and probably represent a minimum value of fire in the record, since the method is best used for determining the occurrence of major fires at the site. The method has not been previously used for sites where a regime of frequent, small fires is prevalent.

Figure 8 shows the CHAR (charcoal accumulation rate) and fire event frequency for Soledad Pond (see figure caption for explanation). Also shown ("+" symbol) are the locations of where the CHAR exceeds the background, signifying the occurrence of a fire event. The charcoal concentration record for Soledad Pond (Figure 3) shows that charcoal deposition has

been relatively constant throughout the entire 12,000-year record. Because of this there are few peaks that rise above the background. Consequently the fire event frequency for the entire record varies from ca. 1 event / 1000 years to a maximum of 4.5 events / 1000 years. When viewed over the entire record, fire events are high between ca. 10,000 and 9,000 years ago, lowest between ca. 9,000 and 6,500 years ago, and increase for the remainder of the Holocene, reaching their maximum during the historic period.

Figure 9 shows the same parameters for the shorter Abalone Rocks Marsh record. In contrast to the charcoal concentration for Soledad Pond, the charcoal concentration for Abalone Rocks Marsh (Figure 7) shows fire events with large charcoal peaks alternating with periods of low charcoal deposition. This is reflected in the CHAR values, and the number of fire event peaks ("+") (Figure 9), suggesting a somewhat different fire regime in the Abalone Rocks Marsh drainage than found in the interior site. Here the fire event frequency varies from a minimum of ca. 5.5 to a maximum of over 9.0 fire events / 1000 years. Fire event frequency is lowest between ca. 6,500 and 6,000 years ago, and 4,500 and 3,500 years ago. As at Soledad Pond, fire event frequency is greatest during the historic period.

Why is the fire event frequency relatively low for Soledad Pond when compared to that for Abalone Rocks Marsh? The explanation may lie in the characteristics of the vegetation at each location during the Holocene, and in the relative sizes of the drainage basins. Considering Soledad Pond, even though there is plenty of charcoal in the record, there are few peaks differentiated from the background. This suggests that fire may actually have been more frequent in the interior, so that fuel buildup was less overall and more catastrophic fires were rare. Evidence for this comes from the relative abundance of grass pollen during both the early and late Holocene, when fire event frequency was the highest. Conversely, at Abalone Rocks Marsh, indicators of coastal sage scrub are important throughout the record. This vegetation type contains many woody species which, when burned, produce more charcoal than does grassland. In addition, the much larger drainage basin feeding into Abalone Rocks Marsh could provide greater amounts of charcoal than could the very small drainage basin surrounding Soledad Pond.

In any event, it is fascinating to note that both sites show an increase in fire event frequency over the last ca. 5,000 years. What can account for this increase? The two most logical factors are an increase in fire due to climatic changes, or the effects of prehistoric human impact on the island. At the present time it is virtually impossible to specify the relative importance of climate and human factors on the fire history. The very short historical record of

natural fires on the Channel Islands (Junak *et al.* 1995) suggests that lightning-caused fires are rare there. On the other hand, Carroll *et al.* (1993) suggested that the island Chumash or their predecessors may have set fires purposely for management of vegetation resources. Perhaps with additional data from archaeological sites on the island, and greater attention to synoptic paleoclimatology in the future, we will be able to sort out the relative importance of the two factors.

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Appendix 1

MODERN POLLEN COLLECTIONS ON SANTA ROSA ISLAND
2 June – 11 June 1999

Modern Pollen Samples; flowers (all on Santa Rosa and San Miguel Islands, Santa Barbara County, CA):
RSA = R. Scott Anderson
MJP = Mitchell J. Power
SC = Sarah Chaney

Collected: Water Canyon "Pond", Water Canyon Road, Santa Rosa Island Quadrangle, m elevation, lat and long. Date Collected: 2 June 1999. Collectors:

1. LAMIACEAE: *Lepechinia fragrans* (RSA, MJP, SC)
2. POLYGONACEAE: *Chorizanthe wheeleri* (RSA, MJP, SC)
3. RUBIACEAE: *Galium nuttallii* ssp. *insulari* (RSA, MJP, SC)
4. ROSACEAE: *Adenostema fasciculatum* (RSA, MJP, SC)

Collected: Carrington Point, mostly on dune fields, Santa Rosa Island North Quadrangle, ca. 122 m elevation, 34° 01' 30" N, 120° 03' 45" W. Date Collected: 2 June 1999. Collectors:

5. NYCTAGINACEAE: *Abronia umbellata* (RSA, MJP, SC)
6. HYDROPHYLLACEAE: *Phacelia distans* (RSA, MJP, SC)
7. RANUNCULACEAE: *Delphinium parryi* ssp. *maritimum* (RSA, MJP, SC)
8. FABACEAE: *Lupinus albifrons* (RSA, MJP, SC)
9. MALVACEAE: *Sidalcea malviflora* (RSA, MJP, SC)
10. ASTERACEAE: *Lasthenia californica* (RSA, MJP, SC)
11. ASTERACEAE: *Layia platyglossa* (RSA, MJP, SC)

Collected: East end around and near Skunk Point, mouth of Old Ranch Canyon, Santa Rosa Island East Quadrangle, ca. 7-30 m elevation, ca. 33° 58' 30" N, 119° 59' 00" W. Date Collected: 3 June 1999. Collectors:

12. ASTERACEAE: *Lessingia filaginifolia*, (RSA, MJP, SC)
13. SCHROPHULARIACEAE: *Castilleja* (*Orthocarpus*) *purpurescens* (RSA, MJP, SC) [on dune sand]
14. CACTACEAE: *Opuntia littoralis* (RSA, MJP, SC) [on dune sand]
15. ASTERACEAE: *Achillea millifollium* (RSA, MJP, SC)
16. ASTERACEAE: *Ambrosia chamissonis* (RSA, MJP, SC) [Old Ranch Wash Canyon?]
17. ONAGRACEAE: *Camissonia cheiranthifolia* (RSA, MJP, SC) [on dunes]

Collected: Karan's Canyon (informal), Transect 70, Tributary to Cherry Canyon, Road to Black Mountain, Santa Rosa Island North Quadrangle, ca. 214 m elevation, 33° 59' 30: N, 120° 04' 00" W. Date Collected: 3 June 1999. Collectors:

18. SCHROPHULARIACEAE: *Mimulus flemingi* (RSA, MJP, SC)
19. PLUMBAGINACEAE: *Armeria maritima* (RSA, MJP, SC)
20. ROSACEAE: *Prunus ilicifolia lyonii* (RSA, MJP, SC)
21. FAGACEAE: *Quercus tomentella* (RSA, MJP, SC)
22. ROSACEAE: *Lyanothamnus asplenifolius* ssp *asplenifolius* (RSA, MJP, SC)
23. PAPAVERACEAE: *Dendromecon rigida* ssp *harfordii* (RSA, MJP, SC)
24. ERICACEAE: *Comarostaphylis diversifolia* ssp *planifolia* (RSA, MJP, SC)

Collected: Black Mountain Road, Black Mountain Hairpin, Santa Rosa Island North Quadrangle, ca. 267 m elevation, 33° 59' 00" N, 120° 04' 00" W. Date Collected: 3 June 1999. Collectors:

25. PINACEAE: *Pinus muricata* (RSA, MJP, SC)

Collected: Black Mountain Road, head of Cherry Canyon, below Bishop Pine stand, Santa Rosa Island North Quadrangle, ca. 236 m elevation, 33° 59' 45" N, 120° 04' 00" W. Date Collected: 4 June 1999 (?). Collectors:

26. LAMIACEAE: *Salvia brandegeei* (RSA, MJP, SC)
27. FABACEAE: *Lotus dendroidius* var *dendroidius* (RSA, MJP, SC)
28. ASTERACEAE: *Eriophyllum confertiflorum* (RSA, MJP, SC)

Collected: Soledad Sagpond, Black Mountain – Soledad Mountain Road, Santa Rosa Island North Quadrangle, ca. 267 m elevation, 33° 57' 50" N, 120° 06' 00" W. Date Collected: 4 June 1999 (?). Collectors:

29. SOLANACEAE: *Petunia parviflora* (RSA, MJP, SC)

Collected: Verde (Green) Canyon, off of Smith Highway, Santa Rosa Island North Quadrangle, ca. 65 m elevation, 34° 00' 20" N, 120° 06' 20" W. Date Collected: 4 June 1999 (?). Collectors:

30. SCHROPHULARIACEAE: Mimulus guttatus (RSA, MJP, SC)

Collected: Near Dry Lake Airstrip, San Miguel Island, San Miguel Island West Quadrangle, ca. 0-33 m elevation, ca. 34° 03' N, 120° 25' W. Date Collected: 6 June 1999. Collectors:

31. ASTERACEAE: *Erigeron glaucus* (RSA, MJP, SC)
32. AIZOACEAE: *Caprobrotus chilensis* (RSA, MJP, SC)
33. PAPAVERACEAE: *Eschscholtzia californica* (RSA, MJP, SC)
34. FABACEAE: *Astragalus miguelensis* (RSA, MJP, SC)
35. CONVOLVULACEAE: *Calistegia macrostegia* ssp *macrostegia* (RSA, MJP, SC)
36. IRIDACEAE: *Sisyrinchium bellum* (RSA, MJP, SC)
37. FABACEAE: *Lotus dendroidius* var *veatchii* (RSA, MJP, SC)
38. FABACEAE: *Lupinus albifrons* (RSA, MJP, SC)
39. ASTERACEAE: *Malacothrix incana* (RSA, MJP, SC)

Collected: Tecolote (Owl) Canyon, off of Smith Highway, Santa Rosa Island West Quadrangle, (40 & 41 = ca. 60 m elevation, 33° 59' 30" N, 120° 10' 20" W); (42 & 43 = ca. 2 m elevation, 34° 00' 15" N, 120° 11' 20" W). Date Collected: 7 June 1999. Collectors:

40. HYDROPHYLLACEAE: *Phacelia grandiflora* (RSA, MJP, SC)
41. ASTERACEAE: Malacothrix saxatilis implicata (RSA, MJP, SC)
42. NYCTAGINACEAE: *Abronia maritima* (RSA, MJP, SC); on beach at canyon mouth.
43. BRASSICACEAE: Cakile maritima (RSA, MJP, SC); on beach at canyon mouth.

Collected: Pablo Peak Road, off the East End Road, Santa Rosa Island Quadrangle, m elevation, lat. and long. Date Collected: 8 June 1999. Collectors:

44. ASTERACEAE: *Grindelia XXXXXXX* (RSA, MJP, SC)
45. FABACEAE: *Astragalus trichopodas* var. *lonchus* (RSA, MJP, SC)

Collected: Soledad Sagpond, Black Mountain – Soledad Mountain Road, Santa Rosa Island North Quadrangle, ca. 267 m elevation, 33° 57' 50" N, 120° 06' 00" W. Date Collected: 10 June 1999. Collectors:

46. GERANIACEAE: *Erodium moschatum* (RSA, MJP, SC)

Collected: Arlington Canyon, off of Smith Highway, Santa Rosa Island West Quadrangle, (47 = ca. 23 m elevation, 34° 00' 00" N, 120° 10' 15" W); (48 = ca. 2 m elevation, 34° 00' 15:N, 120° 10' 30" W). Date Collected: 10 June 1999. Collectors:

47. CARYOPHYLLACEAE: *Spergularia macrothera* (RSA, MJP, SC)
48. ASTERACEAE: *Ambrosia chamissonis* (RSA, MJP, SC); mouth of Arlington Canyon on beach.

Collected: Abalone Rocks Marsh, East End Road, Santa Rosa Island East Quadrangle, sea level, 33° 57' 15: N, 119° 58' 20" W. Date Collected: 11 June 1999. Collectors:

49. FRANKENIACEAE: *Frankenia salina* (RSA, MJP)

Collected: Torrey Pine Stand, East End Road, Santa Rosa Island East Quadrangle, ca. 75 m elevation, 33° 59' 00" N, 119° 01' 15" W. Date Collected: 11 June 1999. Collectors:

50. PINACEAE: *Pinus torreyana* (RSA)
51. PRIMULACEAE: *Anagallis arvensis* (RSA); in grass below torrey pine stand.

Collected: Near the "Hilton" Apartments, Santa Rosa Island North Quadrangle, ca. 90 m elevation, 33° 39' 50" N, 120° 03' 45" W. Date Collected: 11 June 1999. Collectors:

52: RHAMNACEAE: *Ceanothus arboreus* var *glaber* (RSA, SC)

Collected: At the Stiff Leg Boat Dock, at the Ranch, Santa Rosa Island North Quadrangle, ca. 15 m elevation, 34° 00' 40" N, 120° 02' 45" W. Date Collected: 11 June 1999. Collectors:

53. ASTERACEAE: *Coreopsis gigantea* (RSA)

Version 3: RSA 2 Feb 2000

Appendix 2

ASTERACEAE POLLEN TYPES FOR THE CHANNEL ISLANDS

Scott Anderson and Renata Brunner-Jass

3 May 2000

Asteraceae Pollen Type	Example Genera
Ambrosia-type	*Ambrosia* *Iva* *Xanthium*
Characteristics: C3P3, small spines, suboblate to spheroidal	
Artemisia-type	*Artemisia*
Characteristics: C3P3, spheroidal to subprolate, thick exine in intercolpium	
Cirsium-type	*Cirsium* *Centaurea* +?*Arctium*
Characteristics: large grain (gen > 40μ), spines with very broad base	
Lactuceae-type	*Cichorium* *Lactuca* *Taraxacum* *Hieracium* *Microseris* *(Rafinesquia)* *(Stephanomeria)* *Uropapus*? [note: Jepson confirms]
Characteristics: fenestrate or (pseudofenestrate)	
Baccharis-type	*Baccharis* *Brickellia* *Conyza* *Encelia* *Erigeron* *Grindelia* *Gutierrezia* *Heterotheca* *Layia* *Perityle* *Pluchea* *Senecio*
Characteristics: C3/C3P3, ~ 25μ, spine "spikey", spine length:breadth ca. 1/1, Spheroidal	

Helianthus-type — *Coreopsis*, *Helianthus*, *Madia*, *Viquiera (Heliomeris)*

Characteristics: C3P3, spine length:breadth ca. 2/1, spine up to ca. 5μlong, slender(gracile)spines, distinct transverse furrow present

Chaenactis-type — *Bebbia*, *Chaenactis*

Characteristics: grain deeply lobed, massive spines

Solidago-type — *Aster*, *Euthamia*, *Gnaphalium*, *Solidago*

Characteristics: spine density great, spine often bulbous at base, lightly lobate grain, spine length:breadth ca. 1/1

Achillea-type — *Achillea*, *Anthemis* (Moore picture), *Chrysanthemum*, *Cotula*, *Matricaria* (Moore description)

Characteristics: C3P3, thick exine in the intercolpium like *Artemisia*, except with stout spines, subprolate to prolate, tectum or collumellae give intercolpium reticulate-like appearance between spines

Malacothrix-type — *Malacothrix*

Characteristics: C3, large, suboblate to spheroidal grain with broad furrow, spines numerous but short [note: Jepson indicates that this probably belongs to the Lactuceae/Liguliflorae tribe, so perhaps it is "Pseudofenestrate?"]

Eriophyllum-type — *Eriophyllum*

Characteristics: somewhat like *??Chaenactis*-type, but spine broad at base, more Massive [spine or grain is more massive? Spine I think?]

Appendix 3

DIATOM COUNTS AND ECOLOGICAL PREFERENCES FOR THE ABALONE ROCKS MARSH CORE

Scott W. Starratt (USGS)

Depth (cm)	Freshwater	Fresh/Brackish	Brackish	Brackish/Marine	Marine
2.5	22	25	0	0	0
9.5	2	11	0	0	0
15.5	0	0	0	0	0
20.5	5	0	0	0	0
26.5	0	3	0	0	0
53.5	15	46	0	0	0
59.5	52	103	0	0	0
68.5	23	31	0	0	0
75.5	51	142	0	0	0
82.5	26	124	3	0	0
105.5	66	346	0	0	0
111.5	24	19	1	0	1
116.5	7	4	0	0	0
124.5	19	31	0	0	0
130.5	32	85	0	0	0
141.5	23	47	0	0	0
153.5	9	20	0	0	0
178.5	16	57	0	0	0
188.5	38	70	1	0	0
208.5	5	5	0	0	0
225.5	77	306	3	0	1
239.5	2	0	0	0	0
249.5	31	66	1	0	1
265.6	0	0	0	0	0
286.5	0	0	0	0	0
304.5	12	3	0	0	0
314.5	0	0	0	0	0
330.5	0	0	0	0	0
350.5	5	0	0	0	0
370.5	0	0	0	0	0
395.5	0	0	0	0	0
415.5	0	0	0	0	0
435.5	3	1	0	0	0
454.5	0	1	0	1	0
474.5	6	22	5	0	0
494.5	0	0	0	0	0
513.5	0	0	0	0	0
530.5	0	0	0	0	0
550.5	0	0	0	1	0

562.5	0	9	0	0	0
601.5	6	10	0	0	0
619.5	06	5	0	5	2
634.5	1	2	0	0	0
649.5	7	1	0	0	0
659.5	4	1	7	0	0
675.5	0	4	1	1	1

Figure Captions

Figure 1. Pollen percentage diagram of major terrestrial pollen types identified for Soledad Pond, Santa Rosa Island, California. Bars represent the pollen percentage of each taxon at a specified depth within the profile. Dots represent the occurrence of taxa at ≤ 1%. Ages are either in years AD or in calendar years before present (present being 1950 AD for calibration purposes).

Figure 2. Pollen percentage diagram of differentiated members of the sunflower family (Asteraceae) for Soledad Pond, Santa Rosa Island, California (see text for explanation of pollen types). Bars and ages the same as on Figure 1.

Figure 3. Charcoal concentration (particles / cm3) for the Soledad Pond record. Two fractions are shown – the 125 μ and 250 μ size fractions – along with the total charcoal concentration.

Figure 4. Magnetic susceptibility of the Abalone Rocks Marsh, Santa Rosa Island, California, Core 3. Magnetic susceptibility is measured in electric magnetic units (see text for explanation). Ages are either in years AD or in calendar years before present (present being 1950 AD for calibration purposes).

Figure 5. Pollen percentage diagram of major terrestrial pollen types identified for Abalone Rocks Marsh, Santa Rosa Island, California. Dark silhouettes represent the pollen percentage of each taxon at a specified depth within the profile. Light gray silhouettes represent an exaggeration of 10X. Ages are either in years AD or in calendar years before present (present being 1950 AD for calibration purposes).

Figure 6. Percentage diagram of major wetland and aquatic angiosperm pollen types, along with the major spore types from Abalone Rocks Marsh, Santa Rosa Island, California. Silhouettes and age calculations the same as in Figure 5.

Figure 7. Charcoal concentration (particles / cm3) for the Abalone Rocks Marsh record. Two fractions are shown – the 125 μ and 250 μ size fractions – along with the total charcoal concentration.

Figure 8. Charcoal accumulation rates (CHAR), location of major charcoal peaks ("+") and fire event frequency curve for Soledad Pond core. See Methods section for explanation.

Figure 9. Charcoal accumulation rates (CHAR), location of major charcoal peaks ("+") and fire event frequency curve for Abalone Rocks Marsh core. See Methods section for explanation.

Abalone Rocks Marsh, CHAR

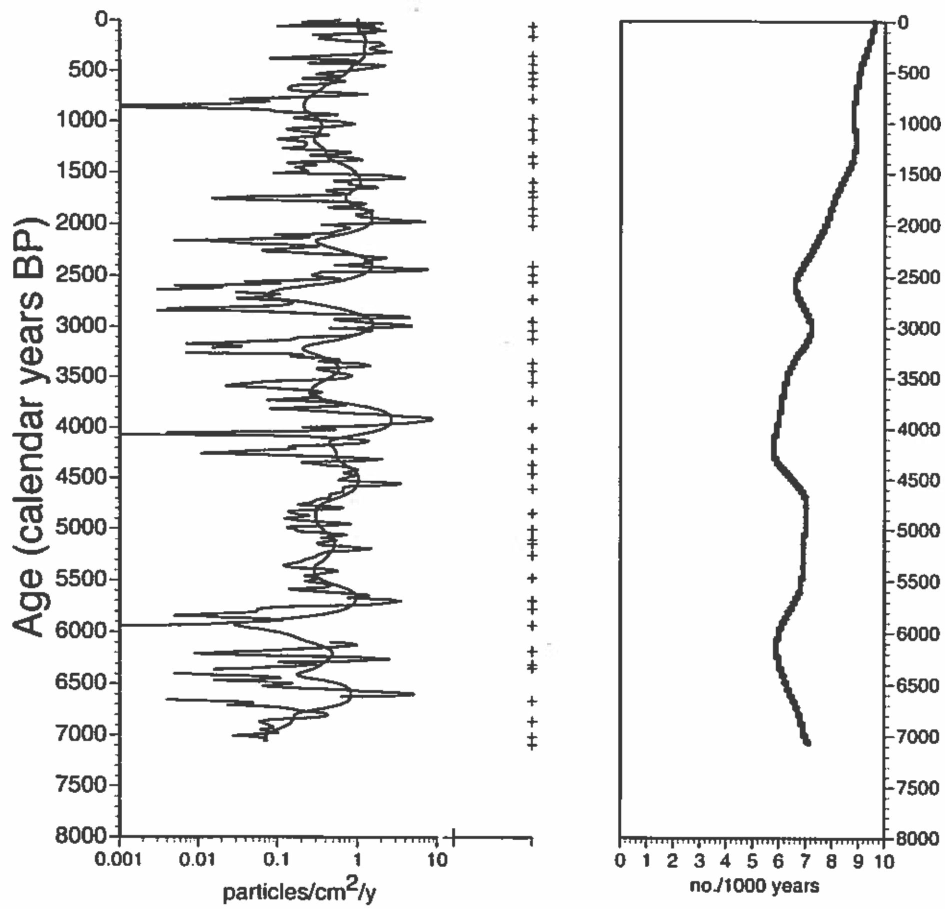

Figure 9.

Soledad Pond, Santa Rosa Island, CA

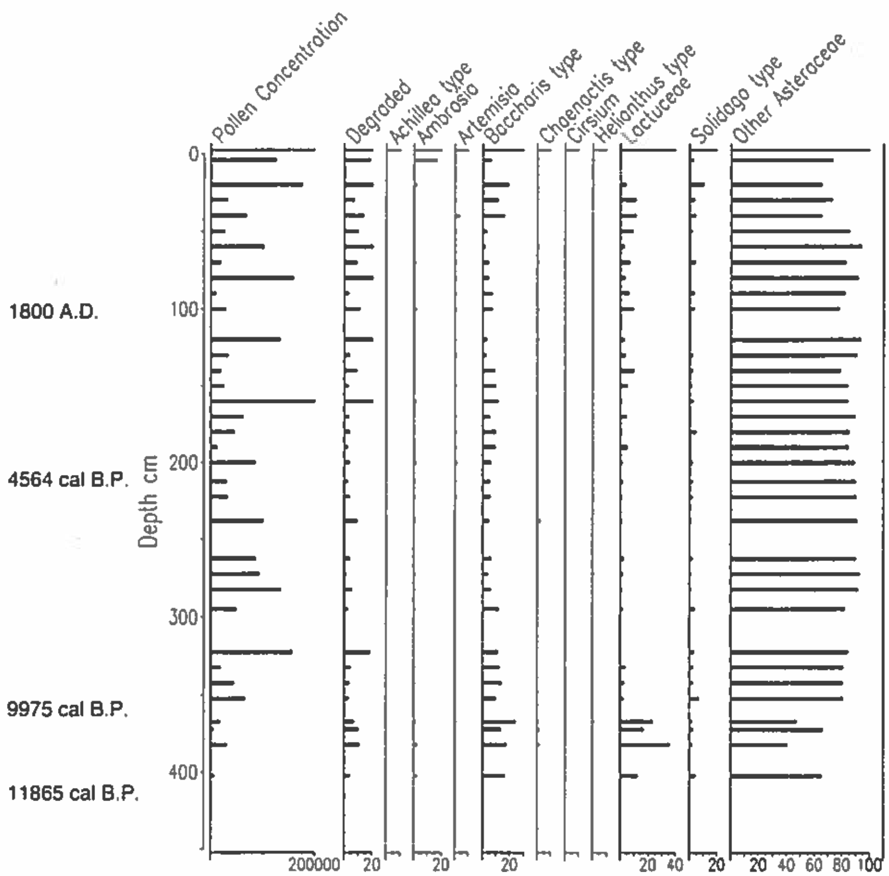

Figure 2.

Soledad Pond, Santa Rosa Island, CA
Charcoal Particle Data

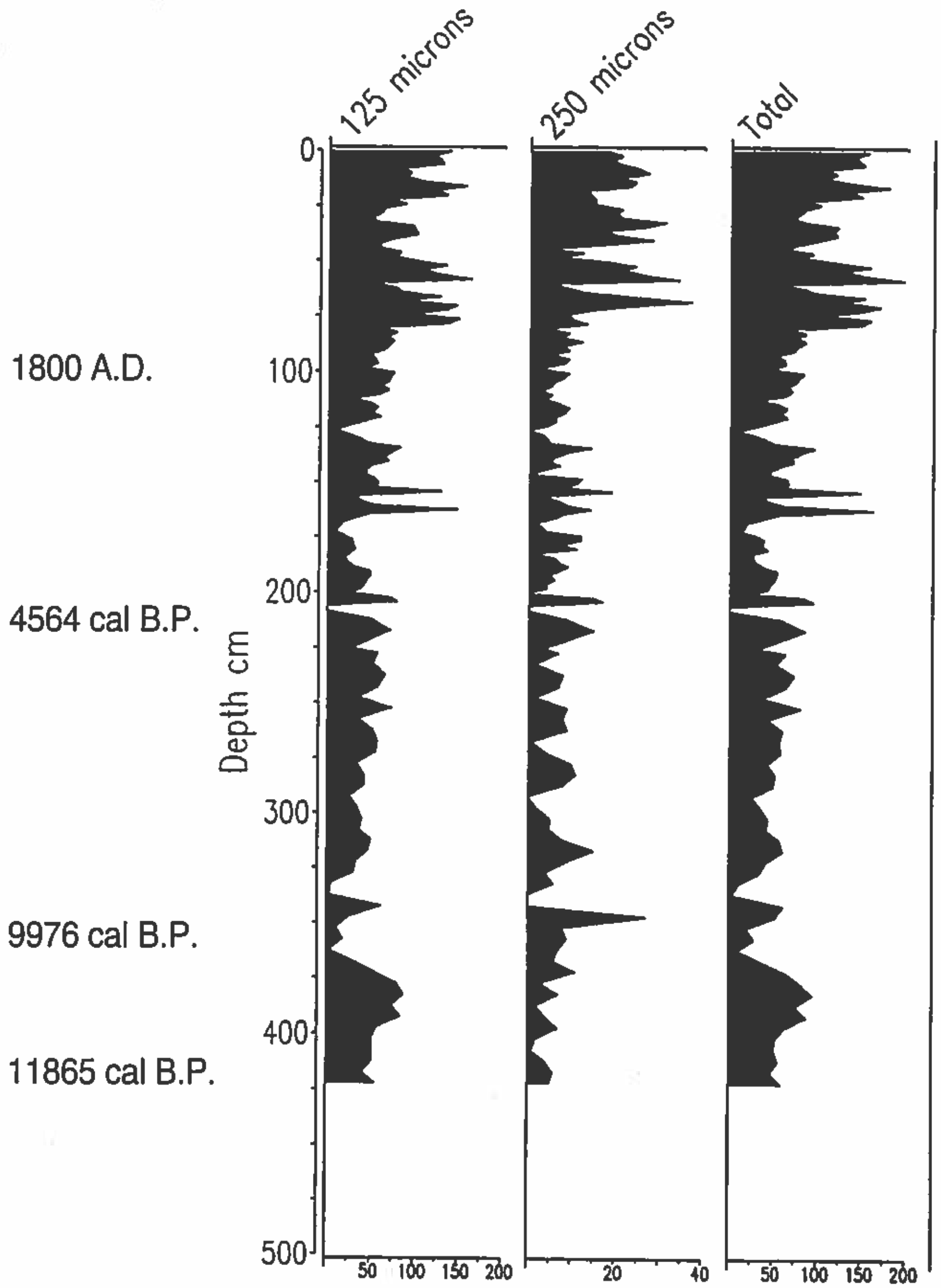

Figure 3.

Abalone Rocks Marsh Core 3, Santa Rosa Island, CA
Magnetic Susceptibility

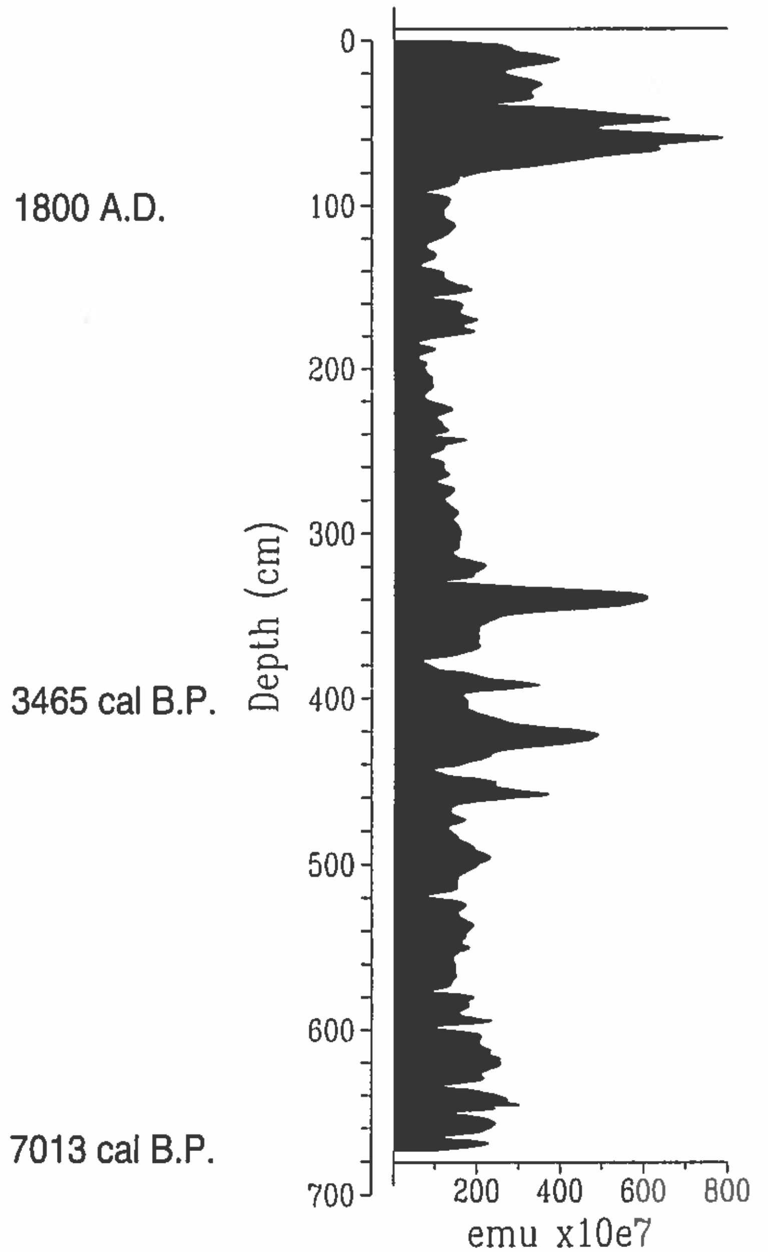

Figure 4.

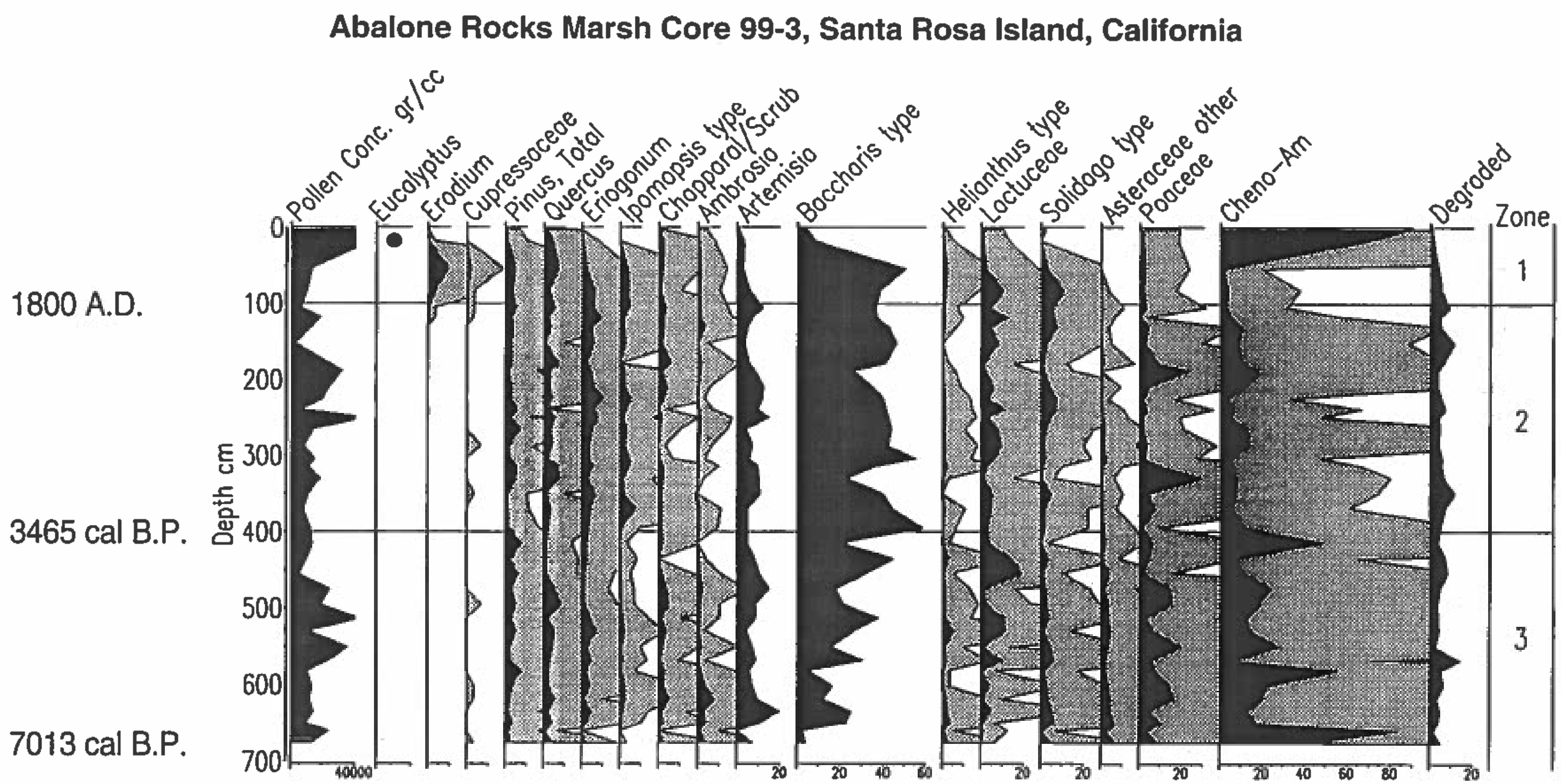
Abalone Rocks Marsh Core 99-3, Santa Rosa Island, California
Pollen Conc. gr/cc
Eucalyptus
Erodium
Cupressaceae
Pinus, Total
Quercus
Eriogonum
Ipomopsis type
Chopporal/Scrub
Ambrosia
Artemisia
Bacchoris type
Helianthus type
Lactuceae
Solidago type
Asteraceae other
Poaceae
Cheno-Am
Degraded
Zone
1
2
3
1800 A.D.
3465 cal B.P.
7013 cal B.P.
Depth cm
0
100
200
300
400
500
600
700
40000
20
40
60
80

Figure 5.

Abalone Rocks Marsh Core 99-3, Santa Rosa Island, California

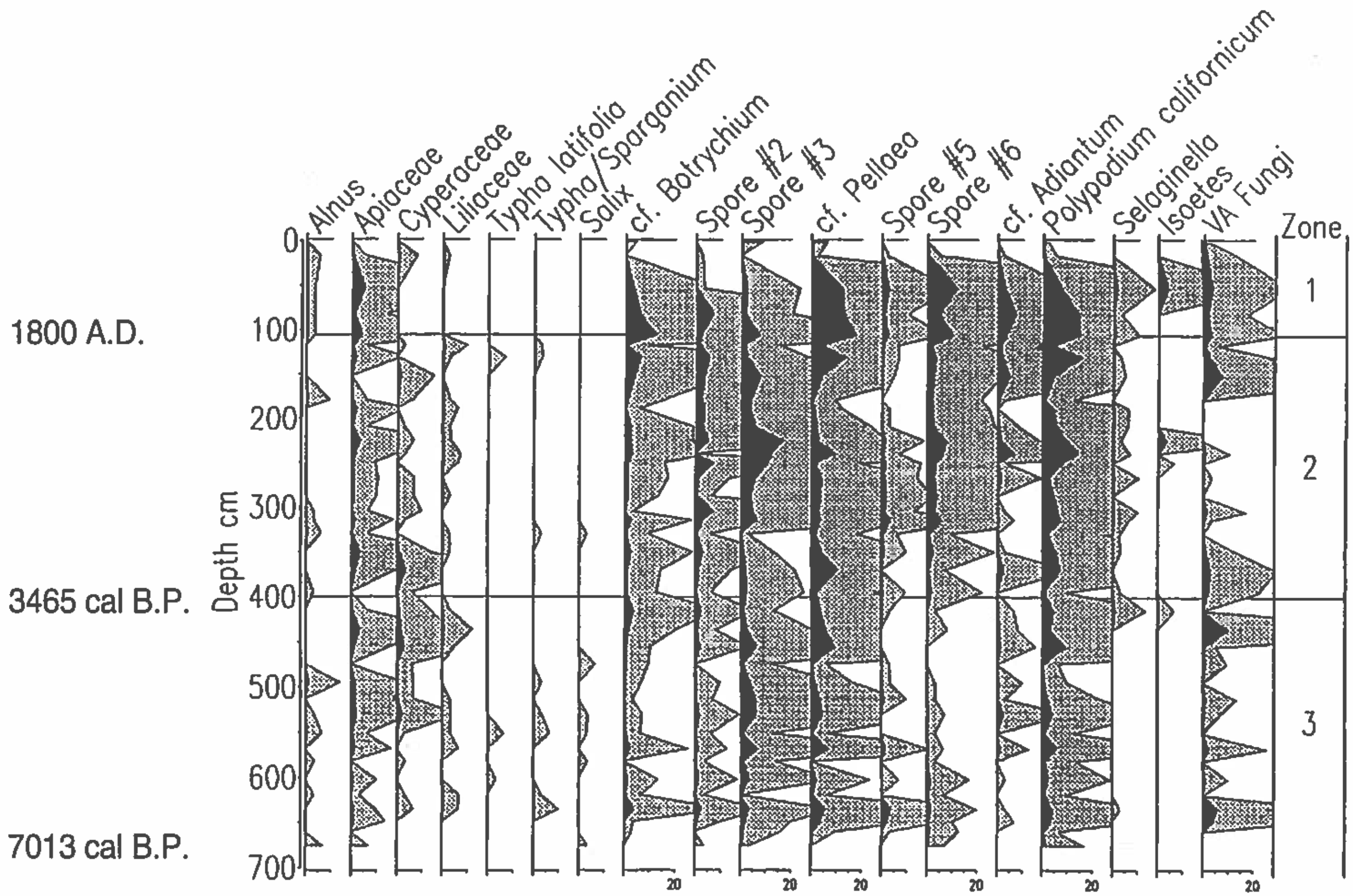

Figure 6.

Abalone Rocks Charcoal Particle Data

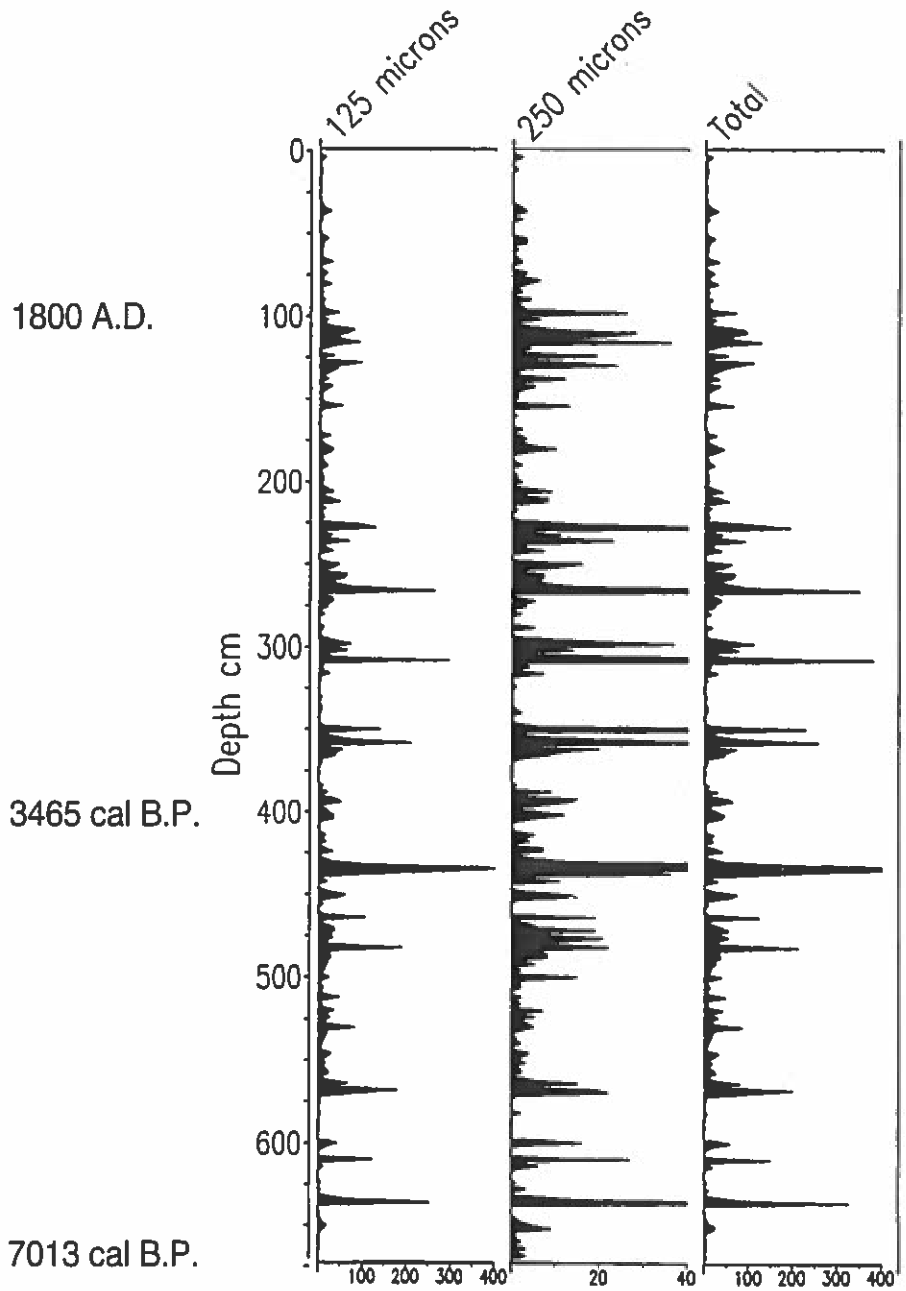

Figure 7.

Soledad Pond, CHAR

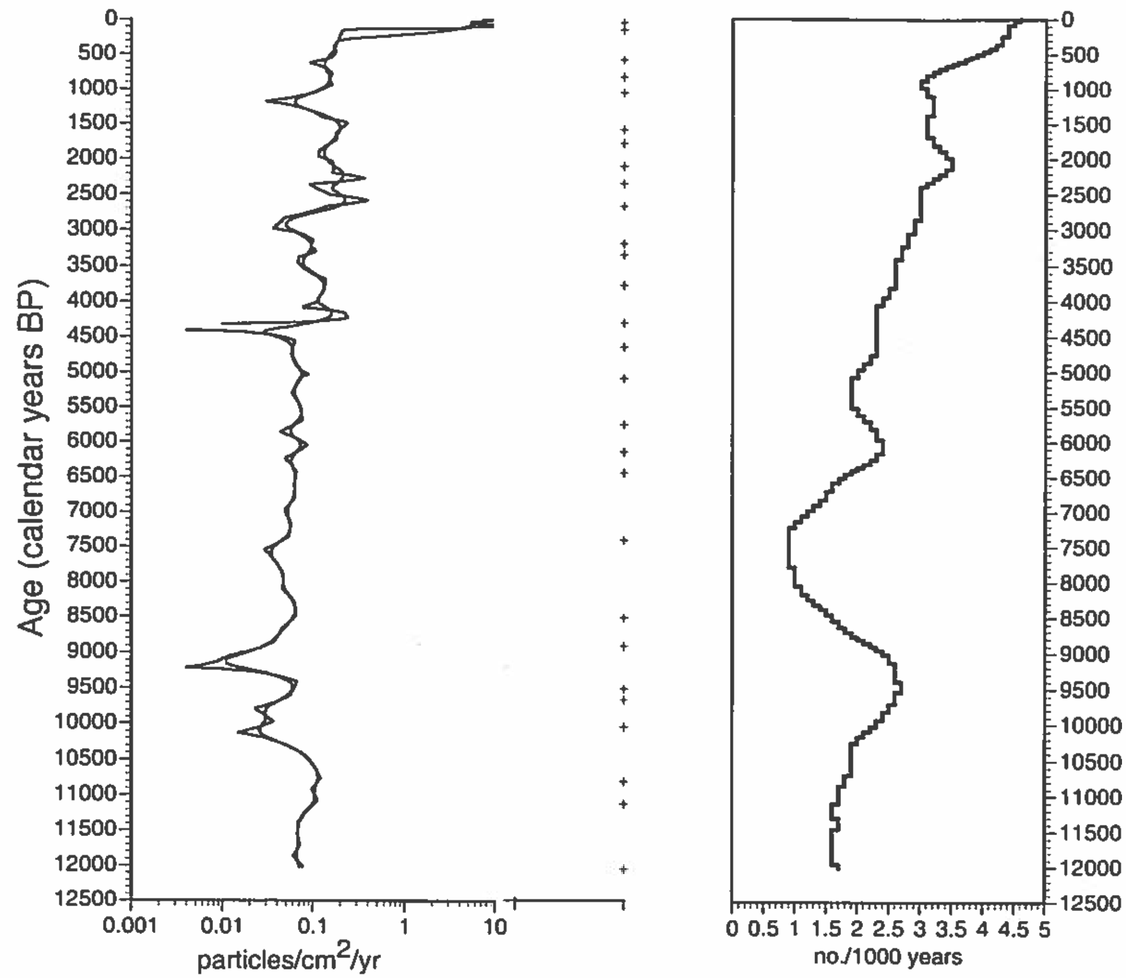

Figure 8.